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THE AUTOINSTRUCTIONAL MATERIALS IN THIS TEXT WERE PREPARED FOR USE IN AN EXPERIMENTAL STUDY, OFFERING SELF-TUTORING MATERIAL FOR LEARNING ATOMIC PHYSICS. THE TOPICS COVERED ARE (1) RADIATION USES AND NUCLEAR FISSION, (2) NUCLEAR REACTORS, (3) ENERGY FROM NUCLEAR REACTORS, (4) NUCLEAR EXPLOSIONS AND FUSION, (5) A COMPREHENSIVE REVIEW, AND (6) A FINAL SUMMARY. (RS)

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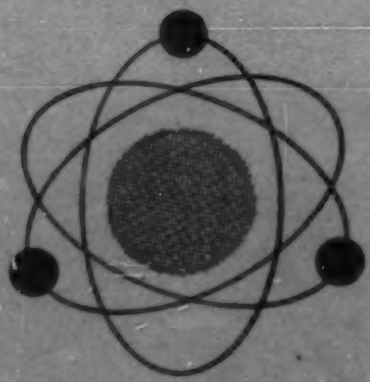
ATOMIC PHYSICS

AN AUTO-INSTRUCTIONAL PROGRAM

David J. Klaus and William A. Deterline

VOLUME 4



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VOLUME 4

David J. Klaus and William A. Deterline

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Pittsburgh Pennsylvania

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These materials were prepared for use in an experimental study of the self-tutoring approach in education. Further information concerning the design of the study and the resulting data are contained in reports available from the American Institute for Research.

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TABLE OF CONTENTS

Volume 4

Unit U: Radiation Uses and Nuclear Fission 1
Unit V: Nuclear Reactors 33
Unit W: Energy from Nuclear Reactors 61
Unit X: Nuclear Explosions and Fusion 93
Unit Y: Comprehensive Review 129
Unit Z: Final Summary 161

Name ______________________

Grade ____________ Age _____

School ______________________

①

UNIT U - Radiation Uses and Nuclear Fission

plus review & Unit T

The first few items of this Unit are review items of the preceding Unit. They are numbered in sequence with a small letter r, an abbreviation for review. After the last review item, the items of this new Unit begin with item number 1. Do not become confused by the numbering of the review items. Simply follow the items in sequence through the book.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER U-4

②

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER U-18

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER U-32

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER U-46

END OF UNIT

START HERE

rT-1 When nuclei are bombarded by particles, a [*] will occur. The new nuclei which are formed are sometimes unstable, that is, they are [ ].

③

U-4 All matter consists of atoms. Since living tissue is made up of [ ], gamma rays passing through living tissue will [ ] some of the atoms in it.

U-18 Radioactive tracers can be used for many purposes in science and industry. A tracer is [**].

U-32 Nuclear reactions can be produced by [**]. They can also occur spontaneously when a [*] decays.

U-46 In this fission reaction, the 92 protons in the $_{92}U^{235}$ nucleus were divided into two new nuclei, one with [#] protons, the other with [#] protons.

$$_{0}n^{1} + {}_{92}U^{235} \longrightarrow {}_{57}La^{144} + {}_{?}Br^{88} + 4\,{}_{0}n^{1} + \text{(energy)}$$

u-3

gamma rays
atoms

④

---

u-17

using a Geiger counter to detect gamma rays (radiations)

---

u-31

bombarded
spontaneous

---

u-45

54
38
2

---

rt-1

nuclear reaction
radioactive

⑤

---

u-4

atoms (matter)
ionize

---

u-18

some radioactive material mixed in with other atoms of the same element

---

u-32

bombarding a nucleus with particles
radioactive isotope (unstable nucleus)

---

u-46

57
35

U-3 The most penetrating radiations emitted by radioactive isotopes are *☐. Since they have momentum, they can ionize some ☐ as they pass through matter.

⑨

U-17 When radioactive phosphorus is added to fertilizers, it is found within a few minutes in the leaves of a plant. The phosphorus is located by **☐ ☐.

U-31 Nuclear reactions can occur when nuclei are ☐ by particles. Nuclear reactions can also occur spontaneously. Radioactive isotopes undergo ☐ nuclear reactions.

U-45 In this fission, the two new elements have Z numbers of #☐ and #☐. The fission also released energy and #☐ neutrons.

$$ {}_{0}n^{1} + {}_{92}U^{235} \longrightarrow {}_{54}Xe^{140} + {}_{38}Sr^{94} + {}_{0}n^{1} + {}_{0}n^{1} + \text{(energy)} $$

---

⑦

rT-2 Many radioactive isotopes are found in nature. In addition to those found in nature, man-made radioactive isotopes can be produced by bombarding ** ______________________________ ________________.

U-5 Living tissue is often killed when its atoms are ________ by high energy waves such as X-rays or the penetrating * ______________ emitted by radioactive isotopes.

U-19 Radiations also may be used to bombard seeds of plants to produce changes called mutations. A change in the inherited structure is called a ______________.

U-33 In a spontaneous nuclear reaction, an __________ nucleus of a radioactive isotope decays by emitting either ** ________ ______________________.

U-47 Lighter atoms generally have about the same number of protons as neutrons; for example, ${}_{8}O^{16}$ has # _____ protons and # _____ neutrons.

u-2

more
charge

⑧

u-16

tracer
radiations

u-30

bombarded
bombard
cyclotron

u-44

neutrons
lighter (separate)
neutrons

rt-2

nuclei to produce nuclear reactions (nuclei with particles)

---

u-5

ionized

gamma rays

---

u-19

mutation

---

u-33

unstable

alpha rays, beta rays, or gamma rays (an electron, a positron, an alpha particle)

---

u-47

8

8

U-2 Gamma rays are ______ penetrating than either alpha or beta particles because gamma rays have no mass and no ______.

(01)

U-16 In agriculture, radioactive phosphorus is used as a ______ material added to the soil. The more phosphorus a plant absorbs, the more ______ it will emit.

U-30 A nuclear reaction can occur when nuclei are ______ by particles. In order to ______ nuclei with high-energy particles, a particle accelerator, such as a ______, is used.

U-44 When heavy nuclei are struck by ______ and fission into two ______ nuclei, some additional ______ usually are emitted.

END OF UNIT

rT-3 Particle accelerators increase the energy of particles by increasing their velocity. The ☐ of a particle increases as its velocity ☐.

⑪

U-6 Gamma rays and other radiations destroy living tissue by ☐ ** .

U-20 New forms of flowers and vegetables have been produced by exposing seeds to ☐ to produce ☐.

U-34 Two types of nuclear reactions are those which result from the ☐ of nuclei by particles, and the ☐ nuclear reactions that occur during radioactive decay.

U-48 Heavy atoms generally have more neutrons than protons, for example, $_{92}U^{235}$ has ☐ # protons and ☐ # neutrons.

u-1

radiations

⑫

u-15

radioactive tracer
Geiger counter

u-29

nuclear reactions
alpha particles
neutron

u-43

neutrons
emitted

u-57

fission
nuclear energy

rt-3

energy
increases

⑬

---

u-6

ionizing atoms in the tissue

---

u-20

radiations
mutations

---

u-34

bombarding
spontaneous (radioactive)

---

u-48

92
143

U-1 Radioactive isotopes are used in medicine, agriculture, industry, and other fields because of the effects of the ______ they emit.

U-15 Both the amount of a substance and its location can be determined by using ______ materials and a ______ to detect the gamma rays emitted.

U-29 Many ______ occur when nuclei are bombarded by particles. In this equation, aluminum ${}_{13}\mathrm{Al}^{27}$ is bombarded by ______ to produce phosphorus ${}_{15}\mathrm{P}^{30}$ plus a ______.

$${}_{13}\mathrm{Al}^{27} + {}_{2}\mathrm{He}^{4} \longrightarrow {}_{15}\mathrm{P}^{30} + {}_{0}\mathrm{n}^{1}$$

U-43 In a fission reaction, a heavy nucleus is bombarded by a neutron. As the nucleus splits into two lighter nuclei, two or three other ______ are usually ______.

U-57 The energy released during the splitting or ______ of a heavy atom is properly called ______.

rT-4 Some particle accelerators, such as the cyclotron, use electric fields to ______________ particles. Particles are accelerated in a ____________ as they pass repeatedly through an •______________________.

⑮

U-7 Gamma rays destroy cancer tissue as well as normal tissue, so cancer patients are often given limited exposures to •________________ emitted by radioactive substances.

U-21 Because radioactive isotopes emit radiations, they are useful in treating cancer by ______________ atoms in cancer tissue; as radioactive __________ material, and to produce hereditary changes called ______________.

U-35 Another type of nuclear reaction is called a fission (rhymes with vision) reaction. Uranium, ${}_{92}U^{235}$, for example, can undergo a nuclear ___________ reaction.

U-49 Lighter atoms generally have about •______________ of protons and neutrons. Heavier atoms, on the other hand, generally have ••____.

rt-11

particle (ion) accelerators
energy (velocity)

91

---

u-14

tracer
gamma rays (radiations)

---

u-28

reactions
nucleus

---

u-42

two parts (two lighter nuclei)
emitted

---

u-56

converted to energy

rt-4

accelerate
cyclotron
electric field

u-7

gamma rays

u-21

ionizing
tracer
mutations

u-35

fission

u-49

equal numbers (the same number)
more neutrons than protons

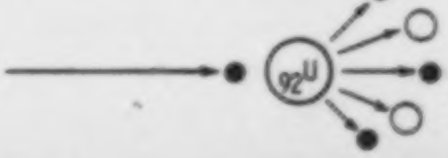
rT-11 The cyclotron and other types of ________ ________ are used to bombard nuclei with high ________ particles, causing nuclear reactions.

(81)

U-14 Calcium atoms in food have been traced to the teeth by adding some radioactive calcium to food as a ________ material, then locating the ________ that it emits.

U-28 There are several kinds of nuclear ________. When any nuclear reaction occurs, there is always some kind of change in the ________ of an atom.

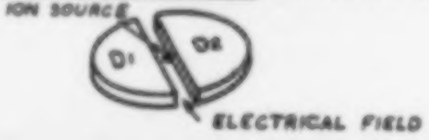
U-42 Fission is the splitting of a nucleus into ________. When fission occurs, some neutrons are usually ________.



U-56 In fission, energy is released because some nuclear mass is ________. This is usually called "atomic energy," but is more appropriately called nuclear energy.

⑲

rT-5 The electric poles in a ______ are called D's. Particles are ______ each time they pass through the *______ between the D's.



U-8 Radium was the first source of gamma rays used to treat cancer. Cobalt, $_{27}Co^{60}$, a man-made radioactive isotope is now more widely used as a **______.

U-22 In beta⁻ decay, ______ are emitted. These particles will pass through small amounts of matter but they are far less ______ than gamma rays.

U-36 During nuclear ______ reactions, the nucleus splits into two parts. When $_{92}U^{235}$ undergoes ______, for example, it *______.

U-50 When a heavy nucleus ______ into two lighter nuclei, the two lighter nuclei cannot contain all the ______ involved. Therefore the extra ______ are emitted separately.

$$_{92}U^{235} \longrightarrow \text{two nuclei} + \text{neutrons} + \text{(energy)}$$

rt-10

velocity (energy)

passes repeatedly through the electric field (between the D's)

02

u-13

tracer (radioactive)

u-27

nuclei (atoms)

nuclear reactions

u-41

heavy

splits into two parts (splits in two lighter nuclei)

u-55

mass being converted to energy

rt-5

cyclotron
accelerated
electric field

21

---

u-8

source of gamma rays (for treating cancer)

---

u-22

electrons
penetrating

---

u-36

fission
fission
splits into two parts

---

u-50

fissions (splits)
neutrons
neutrons

㉒

rT-10 An ion is accelerated to a very high ☐ in a cyclotron because it ☐** ☐.

U-13 Radioactive atoms in food can be used as tracer materials. A Geiger counter can then be used to locate the ☐ materials to find out where the food went in the body.

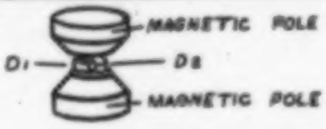
U-27 Man-made radioactive isotopes are produced by bombarding ☐ with particles to cause ☐*.

U-41 Fission is possible only in heavy elements. When fission occurs in the nucleus of a ☐ element such as uranium, the nucleus ☐**.

U-55 The energy released in a fission reaction is another example of ☐**.

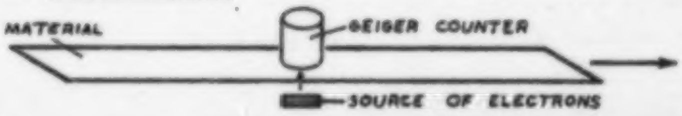
㉓

rT-6 The D's lie between two large magnetic poles which produce a magnetic ________. The electric field exists only between the D's, but the * ________________ also exists inside the D's.

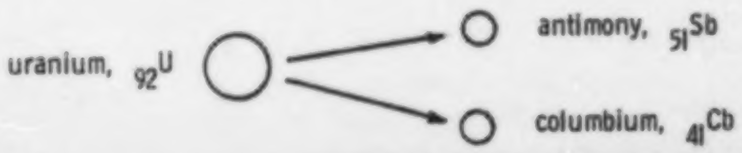


U-9 A needle containing a small amount of radioactive isotope can be surgically inserted in the body near cancer tissue in order to ** ____.

U-23 In industry, the thickness of materials is often determined by the electrons emitted in ________ decay. The thicker the material, the ________ the number of electrons passing through it.



U-37 When a nucleus fissions, each of the two parts turns out to be the ________ of a lighter ________.



U-51 When $_{92}U^{235}$ fissions, two lighter ________ are produced, along with two or three ________ and some ________.

rt-9

velocity (energy)

---

u-12

radiations

---

u-26

radioactive isotopes
radiations

---

u-40

fission
neutrons

---

u-54

gamma
new nuclei (lighter nuclei)
neutrons

rt-6

field

magnetic field

---

u-9

destroy the cancer tissue (ionize atoms in the cancer tissue)

---

u-23

beta^{-} (radioactive)

smaller (fewer)

---

u-37

nucleus (isotope)

element (atom)

---

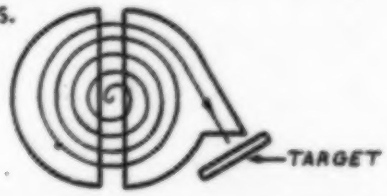
u-51

nuclei

neutrons

energy

rT-9 The ions move in a spiral toward the outside edge of the D's as their ________ increases.



U-12 A radioactive tracer is a bit of radioactive material which, when mixed with stable atoms of the same element, can be identified by the ________ it emits.

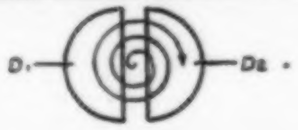
U-26 Both natural and man-made ________ can have unique applications because, unlike non-radioactive substances, they emit ________.

U-40 Nuclear fission is the splitting of a nucleus into two new nuclei. $_{92}U^{235}$ will ________ and split into two lighter nuclei if it is bombarded with ________.

U-54 In fission reactions, energy is released. Some of it as ________ rays, and some is carried away by the momentum of the two ________ and the ________ that are emitted.

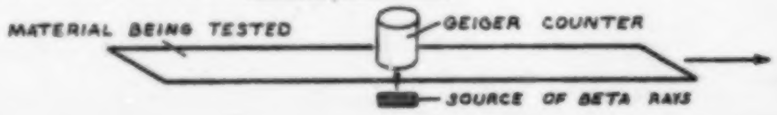
rT-7 The magnetic field bends the path of the ions in a cyclotron so they move in a ☐ path. Thus, the ions will pass repeatedly ☐.

㉗



U-10 Alpha and beta rays will also ☐ atoms and kill tissue, but gamma rays are used to treat cancer because they are more ☐ than the other radiations.

U-24 Changes in the thickness of material are detected by using a Geiger counter to count beta rays. More electrons penetrate thinner material than ☐ material.



U-38 To make a $_{92}U^{235}$ nucleus ☐, or split, it is bombarded with neutrons. The equation before fission occurs is $_0n^1 +$ ☐.

U-52 The mass of the neutron plus the $_{92}U^{235}$ nucleus before fission is always greater than the mass of the two ☐ plus the neutrons that are emitted.

rt-8

negative

28

---

u-11

counter
Geiger counter
radiations (gamma rays)

---

u-25

the thickness of the material

---

u-39

fission
neutrons
splits (fissions) into two lighter nuclei

---

u-53

converted to energy (released as energy)

rt-7

circular (spiral)

through the electric field (the space between the D's)

u-10

ionize

penetrating

u-24

thicker

u-38

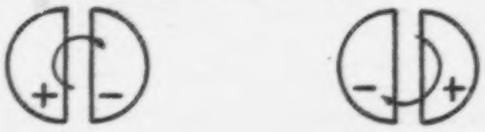
fission

${}_{92}U^{235}$

u-52

new nuclei (lighter nuclei)

rT-8 The D's are made alternately positive and negative so that as positive ions enter the electric field, the D they are approaching has a ______ charge.



U-11 A Geiger ______ detects radiations. The presence of a radioactive isotope in the body can be determined by using a * ______ to detect the ______ it emits.

U-25 If a sheet of material passes between a source of beta rays and a Geiger counter, a change in the rate of clicks from the counter indicates a change in ** ______ ______.

U-39 This equation represents a nuclear ______ reaction. ${}_{92}U^{235}$ is bombarded with ______ and it then ** ______ plus two neutrons.

$${}_0n^1 + {}_{92}U^{235} \longrightarrow {}_{54}Xe^{140} + {}_{38}Sr^{94} + {}_0n^1 + {}_0n^1 + \text{energy}$$

U-53 Some mass always disappears in a fission reaction. The mass that disappears has been ** ______.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER rT-8

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER U-11

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER U-25

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER U-39

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER U-53

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UNIT V - Nuclear Reactions

plus review & Unit U

The first few items of this Unit are review items of the preceding Unit. They are numbered in sequence with a small letter r, an abbreviation for review. After the last review item, the items of this new Unit begin with item number 1. Do not become confused by the numbering of the review items. Simply follow the items in sequence through the book.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER V-3

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER V-15

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER V-27

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER V-39

END OF UNIT

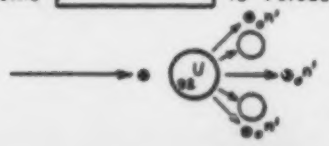
START HERE →

rU-I Radioactive substances have many uses. An isotope is radioactive if its nuclei ** ________________.

㉟

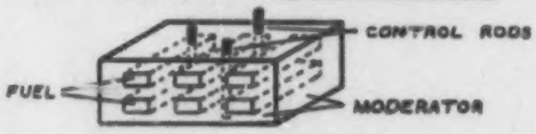
V-3 The energy which is released during nuclear fission can be put to use. Fission can serve as an energy source because during a reaction, mass * ________________.

V-15 When a neutron causes a $_{92}U^{235}$ nucleus to fission, two * ____________ are produced, along with two or three ____________, and some ____________ is released.



V-27 Since each fission generally produces ____________ neutrons than are required to start it, a * ________________ can grow too strong if it is not controlled.

V-39 In addition to a moderator, a reactor has control rods made of boron or cadmium, which absorb ________________, and prevent them from causing more ____________.



v-2

nuclei (elements) (pieces)
neutrons
energy

v-14

fuel
fissions

v-26

moderator
slow down (reduce the speed of)
chain reaction

v-38

fission
chain reaction

v-50

converted to energy
energy
nuclear reactor (reactor's chain reaction)

ru-i

emit radiations (and the nuclei change to a different element)

(37)

---

v-3

is converted into energy

---

v-15

new nuclei (lighter nuclei)
neutrons
energy

---

v-27

more
chain reaction

---

v-39

neutrons
fissions

V-2 When a nucleus undergoes fission, it splits into two lighter ______; 2 or 3 ______ are emitted, and some ______ is released.

V-14 The uranium isotope ${}_{92}U^{235}$ is often used as a ______ in reactors because this isotope ______ readily when it is bombarded with neutrons.

V-26 A material such as carbon is used as a ______ in a nuclear reactor to ______ fast moving neutrons and thus keep the ______ going.

V-38 A series of nuclear ______ reactions that keeps itself going is called a ______.

V-50 Some mass is ______ whenever a heavy nucleus fissions. The rate at which the ______ is released is carefully controlled in a ______.

rU-2 The radiations emitted by radioactive isotopes have momentum and they can ☐ atoms by knocking electrons loose from them.

V-4 To use fission reactions as an energy source, we must produce the fissions, control their rate, and then harness the ☐ that is released.

V-16 When $_{92}U^{235}$ fissions, the neutrons that are emitted travel at very ☐ speeds because so much ☐ is released.

V-28 A chain reaction can be kept from releasing too much ☐ at one time by reducing the number of slow ☐ allowed to hit fuel nuclei.

V-40 The moderator is used to slow down neutrons, while control rods are used to ☐ neutrons. Boron and cadmium are elements used as ☐.

v-1

splits (fissions)
energy

---

v-13

nuclear reactor
fuel

---

v-25

fuel
slow down fast moving neutrons

---

v-37

slow neutrons
fission

---

v-49

energy
fissions
mass

ru-2

ionize

(41)

---

v-4

energy

---

v-16

high
energy

---

v-28

energy
neutrons

---

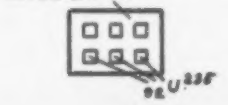
v-40

absorb (stop)
control rods

V-1 A fission reaction occurs when a heavy nucleus ______ into two lighter nuclei. In every nuclear fission reaction, some mass disappears and some ______ is released.

V-13 An isotope that is used as the fissionable material in a *______ is called the fuel. $_{92}U^{235}$ is a commonly used ______.

V-25 A reactor contains a fissionable source of energy, or ______, such as $_{92}U^{235}$, and a moderator to **______ ______ so they will cause more fissions.



V-37 A moderator is needed to slow down the fast-moving neutrons, because *______ are much more likely to cause $_{92}U^{235}$ nuclei to ______ than fast moving neutrons.

V-49 The amount of ______ produced by a reactor depends on the number of ______ occurring at any one time. In each fission some ______ is converted to energy.

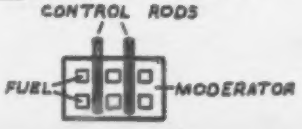
㊸

rU-3 Radioactivity is used in medicine to destroy cancer tissue. Radiations emitted by *__________ will destroy tissue by __________ atoms in the tissue.

V-5 One neutron causes a nucleus to fission, and each fission produces at least one other __________ that can then cause *__________.

V-17 Neutrons which move too fast will tend to bounce off nuclei instead of causing fission. The fast neutrons emitted during fission must be *__________ if they are to cause more fissions.

V-29 Control rods made of materials as boron or cadmium absorb neutrons. The chain reaction in a reactor is controlled by inserting *__________ to absorb neutrons.



V-41 The number of __________ occurring at one time determines the rate at which energy is being __________. This rate is controlled by boron or cadmium *__________.

ru-10

nuclear fission reaction
energy is released (produced)

(44)

---

v-12

chain reaction (fission rate)
controlled
energy

---

v-24

neutrons
chain reaction

---

v-36

fissions
moderator

---

v-48

energy

ru-3

radioactive isotopes (unstable nuclei)
ionizing

(45)

---

v-5

neutron
other fissions (more fissions)

---

v-17

slowed down

---

v-29

control rods

---

v-41

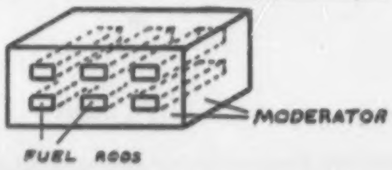
fissions
released
control rods (which absorb neutrons)

IV-10 The splitting of a nucleus into lighter nuclei is called a *__________. Because some mass disappears in this reaction, you know that some **__________ __________.

V-12 In a nuclear reactor, the *__________ proceeds at a __________ rate so that not too much __________ is released all at once.

V-24 The moderator slows the fast moving __________ so that a series of fissions, that is, a *__________, can develop.

V-36 $_{92}U^{235}$ is often used as fuel in a reactor because it __________ readily. The fuel is surrounded by a __________ that slows fast moving neutrons.



V-48 A chain reaction can be controlled to produce any desired level of __________ output up to a limit.

rU-4 In both medicine and industry, radioactive isotopes may be used as tracer materials. These ☐ materials can be located by using a ☐* to detect ☐.

㊼

V-6 Neutrons emitted during fission can cause other fission reactions to occur; a series of ☐ can develop, each releasing still more neutrons plus some ☐.

V-18 Slow moving neutrons are more likely to produce fission in ${}_{92}U^{235}$ than fast moving neutrons, so a reactor must include material that will ☐** so they will cause more ☐.

V-30 Nuclear reactors contain both a moderator and control rods. Neutrons are ☐ by the moderator. In contrast, neutrons are absorbed completely by ☐*.

V-42 A reactor consists basically of a ☐ such as ${}_{92}U^{235}$, a ☐ to slow down fast moving ☐, and ☐* to control the chain reaction.

ru-9

fission
two lighter nuclei (elements)
neutrons

v-11

source of nuclear energy (source of energy from fission reactions)

v-23

nucleus
speed (velocity) (energy)

v-35

neutrons
cause more fissions (keep the chain reaction going)

v-47

twice
energy

ru-4

tracer (radioactive)
radiation counter (Geiger counter)
radiations (gamma rays)

(49)

---

v-6

fissions
energy

---

v-18

slow down neutrons
fissions

---

v-30

slowed
control rods

---

v-42

fuel
moderator
neutrons
control rods

rU-9 When $_{92}U^{235}$ is bombarded by neutrons, a nuclear ☐ reaction occurs. The $_{92}U^{235}$ nucleus splits into ☐ plus two or three ☐, and energy is emitted.

V-11 A nuclear reactor is a controlled ☐ ☐.

V-23 Every time a neutron hits a carbon ☐ in a moderator, its ☐ is reduced.

V-35 A chain reaction is a series of fissions. Each fission produces two lighter nuclei plus two or three ☐ that can ☐.

V-47 The rate of energy output from a reactor depends on how many fissions occur at one time. Having twice as many fissions releases ☐ as much ☐.

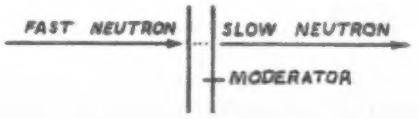
IV-5 Radiations can produce mutations, which are hereditary changes. Scientists are discovering better ways to grow food by using __________ to produce __________ in seeds.

(51)

V-7 A series of fissions that keeps itself going is called a chain reaction. In a continuous __________ each fission is the cause of __________.

fission ⟶ fission ⟶ fission ⟶ etc.

V-19 Fast neutrons are slowed by a material called the moderator. A good __________ for slowing neutrons is a substance, such as water or carbon, containing light atoms.



V-31 A nuclear reactor is kept from producing too much energy by using __________ which reduce the number of __________ that can hit fuel nuclei and cause __________.

V-43 Each fission that occurs produces two __________ nuclei plus two or three __________, which are more than enough to keep a __________ going.

ru-8

nuclei (elements)
fissión

v-10

reactor
controlled
nuclear energy

v-22

moderator

v-34

energy
fission

v-46

critical
neutrons
to keep the chain reaction going (sustain itself)

ru-5

radioactive isotopes
mutations

(53)

v-7

chain reaction
another fission (more fissions)

v-19

moderator

v-31

control rods
neutrons
fissions

v-43

lighter (different)
neutrons
chain reaction

rU-8 Another type of nuclear reaction occurs when a heavy nucleus splits into two lighter ________. This kind of reaction is called a nuclear ________ reaction.

V-10 An atomic bomb is an uncontrolled source of nuclear energy. A nuclear ________, on the other hand, is a carefully ________ source of * ________.

V-22 A neutron is slowed down as it passes through a ________ made of carbon by "bouncing off" of the carbon nuclei.

V-34 Nuclear fission reactions release energy. A nuclear reactor is a controlled source of ________ released during the ________ of heavy nuclei.

V-46 If the fuel must be bombarded with neutrons from an outside source, the reactor is not ________, since it is not producing enough ________ to ** ________ ________.

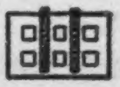
rU-6 When a nuclear reaction occurs, some kind of change occurs in the _____ of an atom. Nuclear reactions can be produced by bombarding _____ with _____.

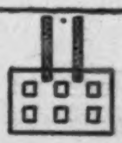
(55)

V-8 Each fission releases two or three extra _____. If these _____ cause more fissions, a •_____ _____ will develop, providing a continuous source of _____.

V-20 The _____ used to slow neutrons is a substance composed of light atoms. Hydrogen and beryllium, for example, have relatively little mass, and are good _____.

V-32 A chain reaction is slowed down when the •_____ _____ are inserted. The chain reaction will grow larger again when ••_____.





V-44 A chain reaction that keeps itself going is self-sustaining, which means that it needs no outside source of _____ to keep the •_____ going.

ru-7

unstable
spontaneous

v-9

reactor (not reaction)
energy

v-21

neutrons
cause more fissions

v-33

fuel
moderator
absorb neutrons (keep the chain reaction under control)

v-45

critical
chain reaction

57

ru-6

nucleus
nuclei
particles

v-8

neutrons
neutrons
chain reaction
energy

v-20

moderator
moderators

v-32

control rods
the control rods are removed

v-44

neutrons
chain reaction (series of fissions)

rU-7 Nuclear reactions can sometimes occur spontaneously. Radioactive isotopes have ________ nuclei that undergo ________ nuclear reactions.

V-9 Fission is the source of energy for both atomic bombs and nuclear reactors. A nuclear ________ is a device to obtain ________ from nuclear fission reactions.

V-21 Carbon is a good moderator and it is often used in nuclear reactors. The carbon moderator slows the ________ so they will be more likely to ** ________.

V-33 A reactor consists of a ________, such as $_{92}U^{235}$, a ________ to slow the neutrons, and control rods to ** ________.

V-45 When a chain reaction is self-sustaining, the reactor is described as "critical." A reactor is ________ when the * ________ keeps itself going.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER rU-7

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER V-9

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER V-21

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER V-33

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER V-45

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61

UNIT W - Energy from Nuclear Reactions

plus review & Unit V

The first few items of this Unit are review items of the preceding Unit. They are numbered in sequence with a small letter r, an abbreviation for review. After the last review item, the items of this new Unit begin with item number 1. Do not become confused by the numbering of the review items. Simply follow the items in sequence through the book.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER W-5

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER W-19

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER W-33

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER W-47

END OF UNIT

START HERE

W-1 When a nucleus undergoes fission, it splits into two lighter ________. Two or three ________ are emitted and some ________ is released.

(63)

W-5 The rate at which fissions occur in a reactor is regulated by the * ________. A high rate of fissions produces a ________ amount of energy.

W-19 A conventional power plant burns coal, turning water into ________ to drive a generator. The heat from a nuclear power plant is also used to ** ________ ________.

W-33 Plutonium, ${}_{94}Pu^{239}$, is a good reactor fuel because, like ${}_{92}U^{235}$, it ________ readily when bombarded with ________.

W-47 The shielding around a reactor must be quite thick and heavy. Dangerous radiations will ________ a thin ________.

w-4

the chain reaction has become self-sustaining (the rate of fissions is great enough to produce enough neutrons to keep the rate of fissions high)

w-13

water
heat (energy)

w-32

element (isotope)

w-46

fuel
moderator
neutrons

rv-1

nuclei
neutrons
energy

---

w-5

control rods
large (high)

---

w-19

steam
turn water to steam to drive a generator

---

w-33

fissions
neutrons

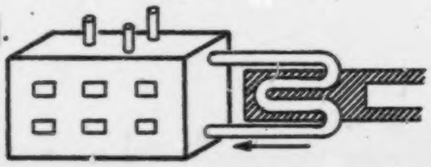
---

w-47

penetrate (pass through)
shielding

W-4 A nuclear reactor which is critical is one in which ____.

W-18 The water which circulates through a reactor is used to heat a second ____ supply. It is then returned to the reactor to collect more ____.



W-32 $_{92}U^{238}$ captures a neutron to become $_{92}U^{239}$, then undergoes two beta minus decays and becomes $_{94}Pu^{239}$, a fissionable isotope of the man-made ____, plutonium.

$$_{92}U^{238} + {}_{0}n^{1} \longrightarrow {}_{92}U^{239} \longrightarrow {}_{93}Np^{239} + {}_{-1}e^{0} \longrightarrow {}_{94}Pu^{239} + {}_{-1}e^{0}$$

W-46 A nuclear reactor consists, basically, of fissionable ____ surrounded by a material called a ____ which slows down fast moving ____. The entire reactor is enclosed in heavy shielding.

rV-2 The neutrons emitted in a fission reaction can cause other fissions to occur; each emitting still more ☐ plus releasing some ☐.

(67)

W-6 As control rods are inserted into a reactor, the number of ☐ occurring is reduced because the rods absorb ☐ and keep them from ☐* ☐.

W-20 A generator produces electrical energy. Both conventional and nuclear power plants use steam to drive a ☐ in order to produce ☐*.

W-34 $_{94}Pu^{239}$ and $_{92}U^{235}$ are used as ☐ in nuclear reactors. These isotopes of the elements ☐ and ☐ both fission readily.

W-48 In order to protect the operators of a reactor from dangerous radiations, the entire reactor is enclosed in a ☐ made of lead or concrete.

89

w-3

critical

w-17

heat

steam

w-31

neutrons

w-45

gamma rays and neutrons (radiations from the reactor)

rv-2

neutrons
energy

(69)

---

w-6

fissions (reactions)
neutrons
causing more fissions (hitting other fuel nuclei)

---

w-20

generator
electrical energy (electricity)

---

w-34

fuel
plutonium (uranium)
uranium (plutonium)

---

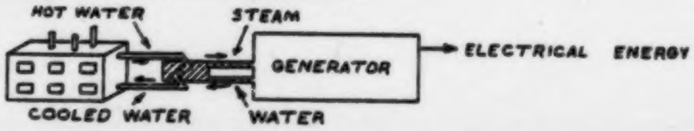
w-48

shielding

W-3 Because each fission produces additional neutrons, a chain reaction will develop. When the chain reaction becomes self-sustaining, the reactor is described as being ☐.

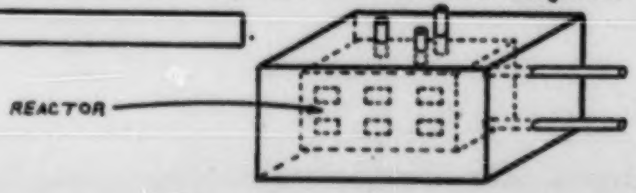
OL

W-17 Water circulating through a reactor gives up its ☐ to another separate water supply which is allowed to turn to steam. The ☐ then drives a generator.



W-31 $_{92}U^{238}$ can be converted to a fissionable fuel by placing it inside a reactor where it can be bombarded by the ☐ produced by fissions.

W-45 A heavy shielding made of materials such as concrete or lead surrounds the entire reactor to protect man from the dangerous ☐.



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rV-3 Each fission produces some neutrons which can cause additional ____. A series of fissions that is self-sustaining is called a * ____.

(71)

W-7 The energy output of a reactor is raised by slowly and partially withdrawing the * ____. This allows the chain reaction to grow until the desired ____ output is reached.

W-21 In some reactors, sodium is circulated through the reactor instead of ____. Sodium is a metal which becomes a liquid at the high ____ produced by a reactor.

W-35 When a heavy atom fissions, it splits into ** ____ ____, several ____ are also emitted, and some ____ is released.

W-49 Control rods absorb ____ and thus control the rate at which fissions occur. When the * ____ in a reactor is self-sustaining, it is said to be ____.

w-2

reactor
moderator

w-16

steam

w-30

it does not fission readily (when bombarded with neutrons)

w-44

neutrons
gamma rays (radiations)

rv-3

fissions (reactions)
chain reaction

(73)

w-7

control rods
energy

w-21

water
temperatures

w-35

two lighter nuclei (atoms)
neutrons
energy

w-49

neutrons
chain reaction
critical

(74)

W-2 Fission reactions are made self-sustaining in a nuclear ________ by mixing the fuel with a material to slow down neutrons. This material is called a ________.

W-16 Water circulating through a reactor becomes heated to several hundred degrees Fahrenheit. The water is kept under pressure to prevent it from turning into ________.

W-30 Only about 1% of uranium found in nature is $_{92}U^{235}$. Most of natural uranium is $_{92}U^{238}$, which is not a good fuel because ________________________.

W-44 Fast moving neutrons are also dangerous. Human beings must be protected from the fast moving ________ and from the penetrating ________ emitted by radioactive isotopes.

---

(75)

rV-4 A controlled source of energy from nuclear fission reactions is a device called a *__________. An atomic bomb is an uncontrolled **__________ __________.

W-8 When the desired energy output is reached, the control rods are adjusted to keep the *__________ at a constant level.

W-22 The water used to cool a reactor will turn to steam unless kept under high pressure. Sodium needs only low pressures because it does not *__________.

W-36 Besides producing energy, reactors also produce the nuclei of lighter __________ which result from the __________ of the fuel nuclei.

W-50 Nuclear energy is released in a reactor in the form of motion of the particles. This energy is converted to __________ as the particles are slowed by the __________.

w-1

energy

---

w-15

heat (energy)

---

w-29

fissions

fission readily

---

w-43

radioactive

gamma rays

rv-4

nuclear reactor
source of energy from nuclear fission reactions

(77)

---

w-8

chain reaction (fissions rate) (energy output)

---

w-22

turn to steam (vaporize)

---

w-36

elements (atoms)
fissioning (fission)

---

w-50

heat
moderator

W-1 Nuclear fission can be a useful source of energy if the reactions can be made self-sustaining, their rate controlled, and if the ________ released can be harnessed.

W-15 The first reactors, such as those designed to power submarines, used water to cool the reactor and carry off the ________ that was produced.

W-29 $_{92}U^{235}$ is a good reactor fuel because it ________ readily. $_{92}U^{238}$, the most abundant uranium isotope, is a poor fuel because it does not ________.

W-43 The radiations from the ________ isotopes in a reactor are dangerous to human beings. The most penetrating of the radiations are the ________.

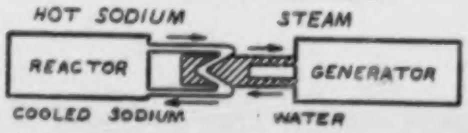
---

rV-5 $_{92}U^{235}$ is used as a ▭ for a reactor because it ▭ readily when bombarded by ▭.

(79)

W-9 In a nuclear reactor, the fission reactions are made self-sustaining by mixing the ▭ with a ▭. The chain reaction is then regulated by means of ▭* ▭.

W-23 When sodium is used to ▭*, it collects heat which is then used to turn water to ▭ which, in turn, drives a ▭.



W-37 Many of the isotopes produced when $_{92}U^{235}$ fissions are radioactive; thus, a nuclear reactor is a source of man-made ▭* as well as ▭.

W-51 Energy is produced in a nuclear reactor by ▭** ▭.

08

rv-10

source of energy (from nuclear fission reactions)
critical
energy

---

w-14

nuclear reactor
heat

---

w-28

fissions
bombarded by neutrons

---

w-42

radiations
decay

81

rv-5

fuel
fissions
neutrons

w-9

fuel
moderator
control rods

w-23

cool a reactor (remove heat from a reactor)
steam
generator

w-37

radioactive isotopes
energy

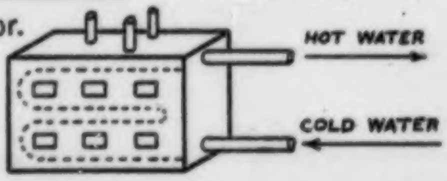
w-51

the fissioning of the fuel (resulting in high speed particles which heat the moderator)

(82)

IV-10 A nuclear reactor is a controlled ** ____________ ____________. When the chain reaction in a reactor is ____________, the reactor produces a continuous output of ____________.

W-14 The useful energy produced by a * ____________ ____________ is in the form of ____________ collected by the cooling liquid flowing through the moderator.



W-28 A good fuel for a reactor is one which ____________ readily when * ________________________.

W-42 The two lighter atoms produced in each fission are usually radioactive, which means they will emit ____________ as they spontaneously ____________.

W-6 Nuclear reactors contain a ________ to slow down fast neutrons, so they will be more likely to cause ** ________________.

(83)

W-10 Each fission produces some energy. A high energy output from a reactor means that ** ________________.

W-24 The nuclear power reactors now being used do not directly produce electrical energy. Instead, they give off ________ which is used to ** ________________.

W-38 Particle accelerators such as the ________, and nuclear reactors are both sources of man-made * ________________.

W-52 In a nuclear reaction, a very small amount of mass is converted to a ** ________________. Thus, nuclear reactors are potential sources of large amounts of ________.

rv-9

fuel
slow down fast neutrons
control the chain reaction (absorb neutrons)

84

---

w-13

moderator (reactor)
heat (energy)

---

w-27

the fuel is used up as it fissions (the impurities interfere with the operation of the reactor)

---

w-41

energy
radioactive isotopes

---

rv-6

moderator

more fuel atoms to fission (more fissions)

---

w-10

many fissions are occurring at once (fissions are occurring at a high rate)

---

w-24

heat (energy)

turn water to steam in order to drive an electrical generator (produce electrical energy)

---

w-38

cyclotron

radioactive isotopes

---

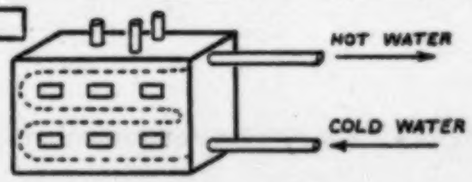
w-52

very large amount of energy

energy

rV-9 A reactor consists basically of a ________ such as $_{92}U^{235}$, a moderator to * ________ and control rods to ** ________.

W-13 The lighter nuclei resulting from fission also carry energy which heats the moderator. Cool water flowing through the ________ is used to absorb this ________



W-27 Periodically, the newly formed elements must be removed and new fuel added to the reactor because ** ________ ________.

W-41 A nuclear reactor is a controlled source of ________ in the form of heat. Reactors also produce * ________ that are useful in medicine and research.

END OF UNIT

IV-7 A ☐ slows neutrons to keep the chain reaction critical. Control rods, however, ☐ neutrons completely so that they will not hit more ☐ nuclei.

(87)

W-11 Once the reaction in a reactor is critical, the ☐ released must be harnessed before it can be used.

W-25 After a $_{92}U^{235}$ nucleus has fissioned, it is no longer useful in a reactor. Eventually almost all of the fuel in a reactor will ☐ into lighter ☐.

W-39 Inside an operating reactor there are large numbers of slow-moving ☐. Any substance inserted into the ☐ will be bombarded by these ☐.

W-53 Nuclear reactors are already being used as a source of energy. Because they emit neutrons and gamma rays, however, they must be surrounded by heavy ☐.

rv-8 energy
control rods
neutrons

---

w-12
slowed down (slowed)

---

w-26
nuclei (elements)

---

w-40
neutrons (particles)
nuclear reactor

---

w-54
heat (energy)

(89)

rv-7

moderator
stop (absorb)
fuel ($_{92}U^{235}$)

---

w-11

energy

---

w-25

fission (change)
nuclei (elements)

---

w-39

neutrons
reactor
neutrons

---

w-53

shielding

rV-8 A chain reaction can be kept from releasing too much ________ by inserting the ________ further into the reactor to absorb some of the ________.

(06)

W-12 The neutrons produced during fission have considerable energy. In a reactor, they give up most of their energy as heat when they are ________ by the moderator.

W-26 As fuel fissions, the newly formed ________ act as impurities that interfere with the operation of the reactor.

W-40 Most natural radioactive isotopes are isotopes of heavier elements. Radioactive isotopes of lighter elements can be produced by bombarding nuclei with ________ in an operating ________.

W-54 If adequate shielding can be devised, reactors of the future may be small enough to use in planes and automobiles, using the ________ from the reactor to generate electricity.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER rV-8

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER W-12

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER W-26

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER W-40

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER W-54

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UNIT X - Nuclear Explosions and Fusion

review W and review X

The first few items of this Unit are review items of the preceding Unit. They are numbered in sequence with a small letter r, an abbreviation for review. After the last review item, the items of this new Unit begin with item number 1. Do not become confused by the numbering of the review items. Simply follow the items in sequence through the book.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER X-5

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER X-21

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER X-37

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER X-53

END OF UNIT

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← START HERE

rW-1 The rate at which fissions occur is controlled by the *__________ in a reactor. A high fission rate releases a __________ amount of __________.

(95)

X-5 In a reactor, the *__________ is controlled so that energy will be __________ at a useful, steady rate.

X-21 Critical mass means **____________________ ____________________.

X-37 The mass of the sun is so great that in a million, million years the sun will lose only 1/16th of its mass. The sun's energy is produced when **____________________ __________.

X-53 The fissions that occur in an atomic bomb explosion produce nuclei of lighter elements which are often radioactive. These nuclei are dangerous because of the __________ they emit.

x-4

energy
controlled
explosion

x-20

amount
chain reaction

x-36

converted to energy
hydrogen

x-52

energy
the joining of lighter nuclei to form a heavier nucleus

rx-10

fission and fusion
fallout

rw-1

control rods
large (high) (great)
energy

97

---

x-5

chain reaction
released (produced)

---

x-21

the smallest amount of fuel in which a (self-sustaining) chain reaction can develop

---

x-37

hydrogen undergoes fusion and becomes helium (mass is converted to energy) (hydrogen is converted to helium)

---

x-53

radiations (radioactivity)

X-4 An explosion occurs when a large amount of ______ is released all at once. If a chain reaction is not ______, an ______ will occur.

X-20 A critical mass of fuel is the smallest ______ of fuel in which a self-sustaining * ______ can develop.

X-36 Over 400 million tons of the sun's mass is * ______ every second as ______ undergoes fusion and becomes helium.

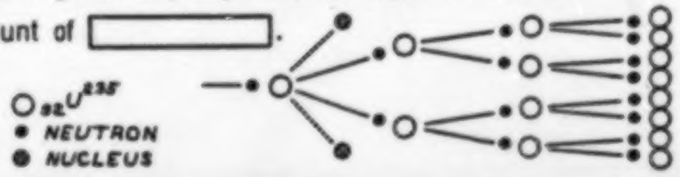
X-52 Nuclear mass is converted to ______ in both fission and fusion reactions. Fission is the splitting of a heavy nucleus into lighter nuclei; fusion is ** ______ ______.

---

rX-10 Radioactive fallout consists of radioactive isotopes produced in both * ______ explosions. The explosion is brief, but danger from ______ continues for long periods afterward.

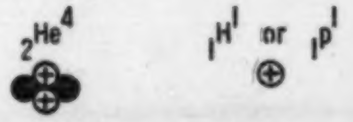
rW-2 Each fission produces some energy. A controlled high energy output from a reactor means that ☐ ☐.

X-6 In an atomic bomb, the chain reaction is ☐ ☐; it grows very large very quickly, and releases a tremendous amount of ☐.



X-22 An atomic bomb must contain more than the ☐ of fuel or the bomb will not ☐.

X-38 A helium nucleus, $_{2}He^{4}$, consists of ☐ particles. A hydrogen nucleus, $_{1}H^{1}$, is a single particle, a ☐.



X-54 "Fallout" consists of matter made radioactive during both ☐ bomb and ☐ bomb explosions. Long after the explosion, there is danger from radioactive ☐.

x-3

controlled
amounts of energy

001

---

x-19

chain reaction
arranged compactly (pushed together)

---

x-35

mass
energy

---

x-51

source of energy
fission

---

rx-9

temperatures (heat)
undergo fusion and become helium

rw-2

fissions are occurring at a high rate (many fissions are occurring at once)

(101)

x-6

not controlled
energy

x-22

critical mass
explode

x-38

4
proton

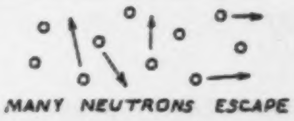
x-54

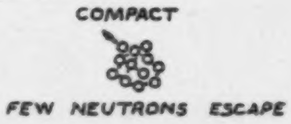
fission (atomic)
fusion (hydrogen)
fallout (isotopes)

X-3 If a chain reaction is not ______ it can grow, and larger and larger *______ will be released.

(201)

X-19 If a critical mass is spread out, a *______ ______ will not develop. To again make the fuel critical, it can be **______.





X-35 In the sun, over 400 million tons of mass is converted to energy every second. Thus, the sun is losing ______ as it radiates ______.

X-51 A controlled source of energy from nuclear fusion has not yet been devised. A nuclear reactor is a controlled *______ ______ from nuclear ______ reactions.

---

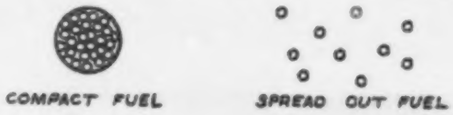
rX-9 A hydrogen bomb requires an atomic bomb to "trigger it" by producing the high ______ needed to cause hydrogen to **______.

rW-3 The energy produced by fission reactions is primarily in the form of [ ], which can be absorbed by water flowing [*].

(103)

X-7 One neutron is needed to produce each fission. In turn, each fission produces 2 or 3 [ ] which can cause other fuel nuclei to [ ].

X-23 If a bomb's fuel is tightly packed, [ ] will strike other fuel nuclei and an explosion will occur. If the fuel is spread out, neutrons escape and [**].



X-39 Four protons cannot simply fuse and become ${}_2He^4$, because ${}_2He^4$ contains four nucleons, of which only [#] are protons, and [*].

X-55 Strontium, ${}_{38}Sr^{90}$, is one of the [ ] isotopes that can result from fission of ${}_{92}U^{235}$. This isotope is found in the [ ] from atomic bomb explosions.

$${}_{92}U^{235} + {}_0n^1 \longrightarrow {}_{38}Sr^{90} + {}_{54}Xe^{136} + 10 \text{ neutrons} + \text{energy}$$

x-2

control rods
neutrons

x-18

compactly

x-34

hydrogen
fusion

x-50

energy

rx-8

fusion
converted into energy

rw-3

heat

through the reactor (through the moderator in the reactor)

(105)

x-7

neutrons

fission

x-23

neutrons

no explosion occurs (no chain reaction develops)

x-39

2

2 are neutrons

x-55

radioactive

fallout

X-2 The chain reaction in a reactor could grow larger if not controlled by the ☐ which absorb ☐ and control the rate of fissions.

901

X-18 The amount of material required for a critical mass depends on how compactly the fuel is arranged. Less fuel is required if the fuel is arranged very ☐.

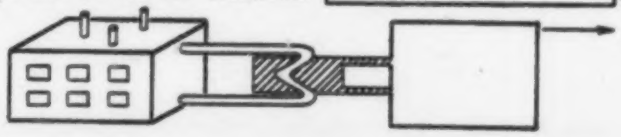
X-34 In our sun, ☐ is converted to helium in a series of ☐ reactions which provide the energy that maintains life on the earth.

X-50 Although the first atomic bomb was equivalent to about 20,000 tons of TNT, a hydrogen bomb can release as much ☐ as 15 or 20 million tons of TNT.

rX-8 The sun is apparently a "fusion furnace." In the sun, hydrogen undergoes ☐ and becomes helium. In the process, some mass is ☐.

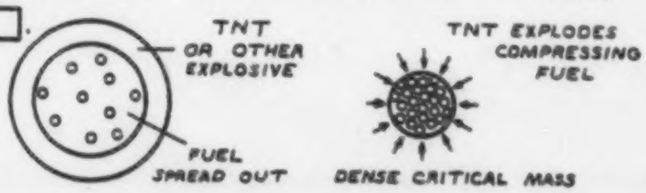
(107)

rW-4 The water that cools the reactor gives up its ______ to another water supply which is allowed to turn to steam. The ______ then drives an electrical ______.



X-8 The neutrons produced by each fission must strike other fuel nuclei if a chain reaction is to develop. If most neutrons miss fuel atoms, ** ______.

X-24 One way of setting off an atomic bomb is to have TNT force fuel into a tightly packed critical mass which then immediately ______.



X-40 One possible way hydrogen becomes helium is through a series of reactions that begins when two ${}_1H^1$ nuclei fuse and form ${}_2He^2$, an isotope of ______.

$$ {}_1H^1 + {}_1H^1 \longrightarrow {}_2He^2 $$
$$ \oplus + \oplus \longrightarrow \oplus\oplus $$

X-56 Radioactive fallout results from both * ______ ______. The actual explosion of a bomb is very brief, but danger from * ______ continues for long periods afterwards.

x-1

energy
released (produced)

801

x-17

fission
neutrons
critical mass

x-33

fusion
energy

x-49

hydrogen
atomic (fission)
temperature

rx-7

lighter
fuse (join) into one heavier nucleus

rw-4

heat
steam
generator

(109)

x-8

a chain reaction will not develop (an explosion will not occur)

x-24

explodes (fissions)

x-40

helium

x-56

fission and fusion bombs (explosions)
radioactive fallout

X-1 Each nuclear fission in a chain reaction releases some energy. In a reactor, the chain reaction is controlled so that too much ______ is not ______ all at once.

011

X-17 Nuclear fuels will undergo ______ when their nuclei are bombarded by ______, but a chain reaction will develop only when a *______ of fuel is present.

X-33 Our sun is apparently a "fusion reactor" -- a nuclear furnace where the ______ of hydrogen nuclei into helium nuclei converts some mass into ______.

X-49 A hydrogen bomb consists of a large supply of isotopes of ______ as fuel, surrounding an ______ bomb which produces the necessary high ______.

---

rX-7 In fission, a heavy nucleus splits into two ______ nuclei. In fusion, two lighter nuclei **______ ______.

rW-5 Nuclear reactors produce energy in the form of ☐ which is removed from the reactor and used to drive a generator to generate ☐.

(111)

X-9 A chain reaction will become critical only if there is enough fuel to make it likely that ☐ will strike ☐.

X-25 When the pieces of fuel in an atomic bomb are pushed together to form a ☐ mass, the chain reaction that develops grows rapidly because it is not ☐.

X-41 Two protons fuse into ${}_2He^2$, which instantaneously emits a ☐ charged positron, and becomes ${}_1H^2$, an isotope of ☐. The ${}_1H^2$ nucleus consists of ☐ ☐.

$$ {}_1H^1 + {}_1H^1 \longrightarrow {}_2He^2 \xrightarrow{\text{beta}^+} {}_1H^2 + {}_{+1}e^0 + \text{energy} $$

X-57 When mass disappears in a nuclear reaction, some ☐. In both fission and fusion reactions some mass is ☐.

rw-12

fuel (element)
moderator
control rods
(211) chain reaction (rate of fissions)

x-16

chain reaction
arranged (distributed)

x-32

lighter
light nuclei
heavier nucleus

x-48

atomic
fusion (heating)

rx-6

fusion bomb
fusion
energy

rw-5

heat
electricity

(113)

x-9

neutrons
nuclei of fuel (more fuel)

x-25

critical
controlled

x-41

positively
hydrogen
one proton and one neutron

x-57

energy is released
converted to energy

rW-12 A nuclear reactor consists, basically, of a fissionable ▭ surrounded by a ▭ to slow down the neutrons, and ▭ to regulate the ▭ ▭.

X-16 The amount of fuel required to develop a self-sustaining ▭ depends upon the type of fuel, what impurities are present, and how the fuel is ▭.

X-32 Fission is the splitting of a heavy nucleus into two ▭ nuclei. Fusion is the joining of two ▭ ▭ to form a ▭.

X-48 Hydrogen will undergo fusion in the intense heat produced by an atomic (fission) bomb. A hydrogen bomb consists of hydrogen plus an ▭ bomb to cause the ▭ of the hydrogen.

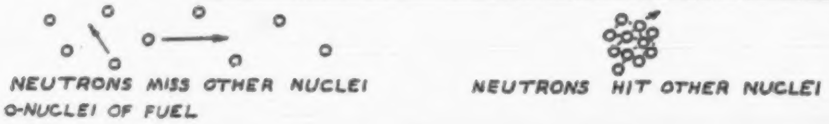
---

rX-6 An atomic bomb is a fission bomb; a hydrogen bomb is a ▭. Both fission and ▭ reactions release ▭ from the conversion of mass.

rW-6 The nuclei of lighter elements that are produced during fission are usually ________; thus, a reactor is a source of man-made *________.

(115)

X-10 For a series of fissions to become ________, there must be a large enough amount of fuel which is tightly packed so that neutrons **________



X-26 An atomic bomb is an uncontrolled source of ________ from *________ reactions. Since the fission reactions in a bomb are not ________, an explosion occurs.

X-42 The first step produces ${}_1H^2$ from two ${}_1H^1$ nuclei. The next step produces ${}_2He^3$, an isotope of ________. The equation indicates that two different isotopes of ________ become one ________ nucleus.

$${}_1H^1 + {}_1H^2 \longrightarrow {}_2He^3 + \text{energy}$$

X-58 The source of energy from both nuclear fission and nuclear fusion is the same: **________ ________.

rw-11

critical
energy

911

x-15

fuel
arranged
amount of fuel (critical mass)

x-31

neutron
isotope (nucleus) (atom)

x-47

temperature
fusion

rx-5

neutrons
chain reaction
explosion

rw-6

radioactive
radioactive isotopes

---

x-10

critical
will strike enough atoms of fuel (to produce a chain reaction)

---

x-26

energy
(nuclear) fission
controlled

---

x-42

helium
hydrogen
helium ($_2He^3$)

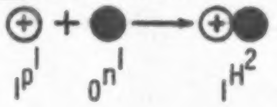
---

x-58

the conversion of some mass into energy (mass is converted to energy) rW-11 When a reactor is self-sustaining it is said to be critical. When a chain reaction becomes ☐, the nuclear reactor continuously releases useful ☐.

X-15 A critical mass of ☐ that has been properly arranged will produce a self-sustaining chain reaction. If the fuel is not properly ☐ a larger ☐* is necessary.

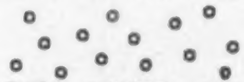
X-31 An example of fusion is ${}_1p^1 + {}_0n^1 \longrightarrow {}_1H^2$. In this reaction a proton and a ☐ fuse or join to become an ☐ of hydrogen.



X-47 A hydrogen (fusion) bomb can be "triggered" by an atomic (fission) bomb which produces the high ☐ needed to cause the ☐ of hydrogen into helium.

---

rX-5 If the fuel in an atomic bomb is spread out, the ☐ escape and no ☐* develops. But if the fuel is compressed, an ☐ occurs.


FUEL SPREAD OUT
NO EXPLOSION

COMPRESSED FUEL
EXPLODES

rW-7 Man-made ____ can also be produced by bombarding nuclei with the ____ emitted during fission in a reactor.

119

X-11 The minimum amount of fuel required to develop a sustained reaction is called the "critical mass." A reactor will not become critical unless it contains at least a ____ of fuel.

X-27 An atomic bomb is a nuclear fission bomb. A hydrogen bomb is a nuclear fusion (few-sion) bomb. Both fission and ____ bombs release energy.

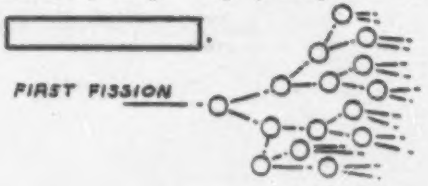
X-43 Two protons first fuse into ${}_1H^2$, which then fuses with another ____ to form ____, an isotope of helium.

Step 1 $\quad {}_1H^1 + {}_1H^1 \longrightarrow {}_1H^2 + {}_{+1}e^0 + \text{energy}$

Step 2 $\quad {}_1H^2 + {}_1H^1 \longrightarrow {}_2He^3 + \text{energy}$

---

rX-1 In an atomic bomb the ____ is not controlled; it grows very large very quickly and releases a tremendous amount of ____.



rw-10

fission

bombarded (struck) by neutrons

x-14

neutrons

striking fuel nuclei (causing more fissions)

x-30

lighter

heavier

x-46

temperature

rx-4

the smallest amount of fuel in which a chain reaction can develop

rw-7

radioactive isotopes
neutrons

(121)

x-11

critical mass

x-27

fusion

x-43

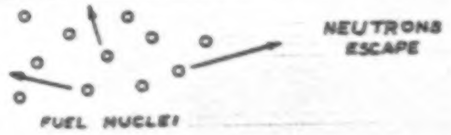
proton ($_1H^1$ nucleus)
$_2He^3$

rx-1

chain reaction (fission reaction)
energy

rW-10 Uranium, $_{92}U^{235}$, and plutonium, $_{94}Pu^{236}$, are good fuels for reactors because they ☐ readily when ☐ **.

X-14 Even when there is a large amount of fuel, if the fuel in a reactor is spread out, most of the ☐ will escape without ☐ **.



X-30 In fission, a heavy nucleus splits into two ☐ nuclei. In fusion, two lighter nuclei join to form one ☐ nucleus.

X-46 Fusion can occur only at a high temperature like that of the sun. For fusion to begin, a source of high ☐ is required.

---

rX-4 Critical mass is defined as ☐ **.

rW-8 Nuclear reactors and particle accelerators, such as the [ ], are sources of [*] that do not exist in nature.

(123)

X-12 An amount of fuel smaller than the [*] will not develop a sustained chain reaction. In some types of reactors, the [*] required is as little as four pounds.

X-28 The source of energy in a hydrogen bomb is nuclear [ ], not nuclear fission. Fission and [ ] are two different types of nuclear reactions.

X-44 In the last step, two ${}_2He^3$ nuclei fuse. Two [ ] are emitted, one [$] nucleus is formed, and [ ] is released.

$${}_2He^3 + {}_2He^3 \longrightarrow {}_2He^4 + {}_1p^1 + {}_1p^1 + \text{energy}$$

---

rX-2 A chain reaction will develop only if the fuel is properly arranged so that the [ ] cannot escape without striking more [ ] nuclei.

rw-9

the fuel is used up as it fissions (the impurities interfere with the operation of the reactor)

x-13

more fissions (a chain reaction)
critical mass

x-29

splitting (breaking)
nuclei (atoms)
nucleus (atom)

x-45

hydrogen
fusion
helium
energy

rx-3

fuel
chain reaction

rw-8

cyclotron
radioactive isotopes

(125)

---

x-12

critical mass
critical mass

---

x-28

fusion
fusion

---

x-44

protons
$_2He^4$
energy

---

rx-2

neutrons
fuel (uranium) ($_{92}U^{235}$)

rW-9 Periodically the fuel in a reactor must be replaced with fresh fuel because **________________________________ ____________________.

X-13 Neutrons produced by fissions will escape without causing *________________ unless there is a *______________ of fuel arranged in just the right way.

X-29 Fission, you remember, means the ____________ of a heavy nucleus. Fusion means that two lighter ____________ "fuse" or join together to form a heavier ____________.

X-45 In this series of reactions, nuclei of ____________ undergo ________ and becomes the element ________. In each step of the series some ________ is released.

---

rX-3 A critical mass is the smallest amount of ________ necessary for a self-sustaining *______________________ to develop.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER rW-9

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER X-13

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER X-29

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER X-45

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER rX-3

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UNIT Y - Comprehensive Review

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER Y-15

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER Y-29

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER Y-43

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER Y-57

END OF UNIT

START HERE

Y-1 All substances are made up of ________, but different substances are made of *________________.

(131)

Y-15 Millikan measured the ________________ on an electron in his *________________ experiment. He was then able to calculate the ________ of an electron using Thomson's e/m ratio.

Y-29 In the reaction, ${}_{2}\mathrm{He}^{4} + {}_{7}\mathrm{N}^{14}$, a proton plus a new nucleus is formed. The new nucleus must consist of #______ nucleons and have a charge of #______.

$${}_{2}\mathrm{He}^{4} + {}_{7}\mathrm{N}^{14} \longrightarrow {}_{1}\mathrm{p}^{1} + ?$$

Y-43 Spontaneous beta^{-} decay involves the emission of an ________________. Chromium, ${}_{24}\mathrm{Cr}^{55}$, beta^{-} decays to Megnesium, Mn, in the reaction -

$${}_{24}\mathrm{Cr}^{55} \longrightarrow \$\_\_\_\_\_\_\_\_ + \$\_\_\_\_\_\_\_\_ + \text{energy}$$

Y-57 When fast moving neutrons strike the moderator, they give up their ________________ in the form of ________. Water circulating through the reactor collects this ________.

y-14

charge/mass ratio
the same (equal)

---

y-28

mass (atomic)
atomic (mass)

---

y-42

$({}_{88}\mathrm{Ra}^{226} \longrightarrow)\ {}_{2}\mathrm{He}^{4} + {}_{86}\mathrm{Rn}^{222}$ (+ energy)

---

y-56

critical
chain (fission)

y-1

atoms
different kinds of atoms

---

y-15

charge
oil drop
mass

---

y-29

17
8

---

y-43

electron
$_{-1}e^{0}$
$_{25}Mn^{55}$

---

y-57

energy
heat
heat (energy)

Y-14 Thomson found that the e/m, or ________ ________, for electrons was always constant. This suggested that all electrons have ________ charge and mass.

Y-28 A nuclear reaction does not change either the total of the ________ numbers or the total of the ________ numbers involved.

Y-42 Radium $_{88}Ra^{226}$ spontaneously alpha decays to become Radon, symbol Rn. The equation for this reaction is written -

$$_{88}Ra^{226} \longrightarrow \boxed{} + \text{energy}$$

Y-56 When a reactor needs no outside neutrons to keep it going, it is described as being ________. The ________ reaction is then self-sustaining.

Y-2 The basic structure of all atoms is the same, a central ________ with ** ________.

(135)

Y-16 Nuclei of atoms of the same element all have the same number of ________, but they may have different numbers of ________.

Y-30 Sometimes mass disappears during a nuclear reaction. When this happens, ** ________. If mass is produced in a reaction, ** ________.

Y-44 Spontaneous beta$^+$ decay involves the emission of a ________. Chromium, $_{24}Cr^{49}$, beta$^+$ decays to Vanadium, V, in the reaction -

$$_{24}Cr^{49} \longrightarrow \$\ \_\_\_\_\_\_\_\_$$

Y-58 A fission reactor produces energy in the form of ________ which is used to turn water to ________ so as to drive an ________ generator.

y-13

charge to mass (charge/mass, e/m)

---

y-27

easily pass through matter
charged

---

y-41

2
4
energy

---

y-55

moderator
control rods

y-2

nucleus
electrons orbiting around it

---

y-16

protons
neutrons

---

y-30

some energy is released
some energy has disappeared

---

y-44

positron
${}_{+1}e^{0} + {}_{23}V^{49}$ (+energy)

---

y-58

heat
steam
electric

Y-13 By measuring both their velocity and amount of deflection, Thomson was able to determine the *____________ ratio of an electron.

Y-27 When Chadwick bombarded beryllium with alpha particles, the particles emitted were very penetrating, which means they **____________ and thus could not be ____________ particles.

Y-41 The emission of an alpha particle reduces Z by #____ and A by #____. The emission of a gamma ray only reduces the excess ____________ in the nucleus.

Y-55 Nuclear reactors include a material to slow down fast moving neutrons. This material is called a ____________. Reactors also contain *____________ to regulate the reaction.

Y-3 The nucleus of an atom consists of two kinds of particles, [*]. Because nuclei contain [ ], they have a [ ] charge.

(139)

Y-17 Nuclei of the same element which have different numbers of neutrons have the same charge but different [ ]. These are atoms of different [ ].

Y-31 The precise relationship between mass and energy was described by Einstein. His equation, E = [$], indicates that very little [ ] can be converted to a [*] [ ].

Y-45 Along with the electron or positron, beta decay also involves the emission of a neutrino. Like photons, [ ] have neither [ ] nor electrical [ ].

Y-59 Radiations, especially the penetrating [ ] rays are dangerous. For this reason, reactors must be surrounded by heavy [ ] consisting of lead or concrete.

y-12

electric field
negative
positive plate

---

y-26

cloud chamber
new nucleus

---

y-40

radiant energy
mass
charge

---

y-54

controlled
energy
fuel

y-3

neutrons and protons
protons
positive

(141)

y-17

masses
isotopes

y-31

mc^2
mass
large amount of energy

y-45

neutrinos
mass
charge

y-59

gamma
shielding

Y-12 The space between two charged metal plates is an ______. Electrons were found to have a ______ charge because they were deflected toward the ______.

Y-26 Nuclear reactions can be observed in a Wilson ______. In every nuclear reaction, a ______ ______ is formed, and a particle may be emitted.

Y-40 Gamma rays consist of bundles of ______ called photons. A photon has no ______ and no electrical ______, but does have momentum.

Y-54 A nuclear reactor is designed to produce a ______ source of ______ from fission reactions. $_{92}U^{235}$ is commonly used as the ______ in reactors because it fissions readily.

Y-4 Electrons have a ______ charge. When an atom has an equal number of positive and negative charges, it is called a ______ atom.

Y-18 All atoms with the same atomic number belong to the same ______. All atoms having the same mass number and the same charge belong to the same ______.

Y-32 The energy needed to hold nuclei together comes from the conversion of ______ as the nucleus is formed. This energy is called nuclear ______ energy.

Y-46 Because isotopes such as $_{92}U^{238}$ and $_{6}C^{14}$ undergo radioactive decay at a regular rate, it is possible to find the ______ of substances containing these isotopes.

Y-60 In an atomic bomb the ______ is uncontrolled and an ______ occurs.

y-11

cathode rays
mass (velocity)
velocity (mass)

---

y-25

velocity
nucleus

---

y-39

electrons
most
energy

---

y-53

neutrons
neutrons
chain reaction

---

y-4

negative
neutral

(145)

y-18

element
isotope

y-32

mass to energy
binding

y-46

age

y-60

chain reaction (fission rate)
explosion

Y-11 Because they came from the cathode of vacuum tubes, electrons were first called ☐. Since they can exert a force, electrons were known to have both ☐ and ☐.

Y-25 Rutherford first observed nuclear reactions when bombarding ${}_7N^{14}$ with ${}_2He^4$. Because protons emerged with a high ☐, he guessed that a collision resulted in a new ☐.

Y-39 Beta rays consist of ☐. Gamma rays are the ☐ penetrating of the radiations. They consist of particle-like bundles of radiant ☐.

Y-53 Fission is caused by bombarding a heavy nucleus with ☐. Since additional ☐ are released by each fission reaction, a self-sustaining ☐ ☐ can develop.

Y-5 Atoms which are not __________ are called ions. A nucleus surrounded by too few electrons is a __________ and a nucleus surrounded by too many electrons is a __________ __________.

(147)

Y-19 The number of protons in a nucleus is indicated by the __________ number, while the total number of nucleons is indicated by the __________.

Y-33 A nucleus always has __________ than the particles making up that nucleus. The mass that disappeared was converted into __________.

Y-47 Radiation is measured by instruments such as the __________ counter, which allows a small amount of current to flow when radiations __________ atoms of gas in the instrument tube.

Y-61 A hydrogen bomb involves a __________ reaction. The joining together of two light nuclei is called __________.

y-10

matter
speed

148

y-24

4
electrons
2 protons and 2 neutrons

y-38

alpha rays (alpha particles)
helium ($_2He^4$)
beta rays (electrons)

y-52

a fission reaction (nuclear fission)
explosion

y-5

neutral
positive ion
negative ion

(149)

y-19

atomic
mass number

y-33

less mass
nuclear binding energy

y-47

Geiger (radiation) (scintillation)
ionize (strike)

y-61

fusion
fusion

(150)

Y-10 Mass is the amount of ________ in an object, and velocity means the ________ at which an object moves.

Y-24 Before neutrons were discovered, a $_2He^4$ nucleus was thought to contain *________ protons and 2 ________. We now know a helium nucleus consists of **________.

Y-38 Least penetrating of the radiations are the *________ ________, which are the nuclei of the element ________. Next in penetrating power are the negatively charged *________.

Y-52 Atomic energy is the name often given to the energy released during *________. If this energy is released all at once, an atomic ________ occurs.

Y-6 Each element consists of atoms which all have the same number of ☐ in their nucleus. There are ☐# stable elements found in nature.

(151)

Y-20 The actual mass of an atom is not indicated by the ☐ number. Actual mass is measured in amu, or ☐.

Y-34 Nuclear reactions can be produced by ☐ nuclei with particles, and they can also occur spontaneously. Spontaneous nuclear reactions occur in ☐ elements such as radium.

Y-48 A particle accelerator is a device used to increase the ☐ of particles and thus increase the likelihood of a ☐.

Y-62 In the sun, hydrogen undergoes ☐ and becomes the element ☐, releasing large amounts of ☐ in the process.

y-9

attracted
tends to pull electrons away from the nucleus

y-23

shooting
matter
in a nucleus (at the center)

y-37

alpha rays (alpha particles), beta rays (electrons), and gamma rays

y-51

two lighter nuclei
fission

y-6

protons
92

---

y-20

mass
atomic mass units

---

y-34

bombarding
radioactive (unstable)

---

y-48

velocity (speed) (energy)
nuclear reaction

---

y-62

fusion
helium
energy

Y-9 Even though electrons are ______________ toward the nucleus, they tend to stay in orbit because of centrifugal force which ** ______________________________.

Y-23 Scattering experiments which involved ______________ particles through atoms, demonstrated that most of the space inside atoms contains no ______________, and that the positive charges are concentrated * ______________________.

Y-37 Decaying nuclei emit three different types of radiations. These are ** ______________________________.

Y-51 A type of nuclear reaction involving the splitting of a heavy nucleus into * ______________________ along with neutrons and energy is called ______________.

---

(155)

Y-7 The size of the charge on both protons and electrons is very ________, but because they are unlike charges, protons and electrons * ________________.

Y-21 One sixteenth of the mass of one atom of $_8O^{16}$ is used as the standard in measuring mass in * ________________, abbreviated $ ________.

Y-35 Elements with ________ nuclei emit radiations. As a result of spontaneous radioactive ________, these nuclei change to a * ________________.

Y-49 One type of particle accelerator called a ________, increases the velocity of particles as they repeatedly pass through an ________ field.

Y-63 Nuclear reactions can occur when nuclei are ________ by other particles; spontaneously during radioactive ________; when a heavy nucleus ________; or when lighter nuclei join during ________.

y-8

repel each other
tend to attract each other

---

y-22

deflected (scattered)
evenly distributed

---

y-36

radioactive (unstable)
half-life
half (1/2)

---

y-50

radioactive isotope
tracer

---

y-7

small
attract each other

(157)

---

y-21

atomic mass units
amu's

---

y-35

unstable
decay
different element

---

y-49

cyclotron
electric

---

y-63

bombarded
decay
fissions
fusion

Y-8 Two protons have like charges; they will tend to *__________. Unlike charged objects will **__________.

158

Y-22 Nuclei were discovered by shooting positive particles through atoms. Some particles were widely __________, indicating that charges are not *__________ in an atom.

Y-36 Rate of decay of __________ nuclei is measured in __________, which indicates how long it takes for __________ of a given number of nuclei to decay.

Y-50 The location, or place where atoms of a particular element have gone can be determined by using a *__________ __________ of that element as a __________ material.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER Y-8

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER Y-22

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER Y-36

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER Y-50

END OF UNIT

PRECEDING PAGE BLANK-NOT FILMED

UNIT Z - Final Summary

This final summary consists of forty items, and each item has at least one blank containing two stars (**). Just as you have done before, fill in each of the double star blanks in your own words. Remember to use the words a physicist would use and give as complete an answer as you can. When you turn to the correct answer for an item, you will find that the best answer is printed first, followed by additional acceptable statements.

Look at this sample item:

A neutron is a ** . There are many things you can say about neutrons, but probably the most important basic answer is "a nucleon which has a mass of about 1 amu, and has no electrical charge."

Now go on to the first item, and remember to fill in each blank, giving as complete an answer as you can, using the words a physicist would use.

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER Z-9

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER Z-17

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER Z-25

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER Z-33

END OF UNIT

START HERE

Z-1 All substances are made up of ____________. Elements are substances which ** ______________________________________.

163

Z-9 "Scattering" refers to a type of experiment in which ** ______________________________________.

Z-17 The general rule for attraction and repulsion of charged particles is that ** ______________________________________.

Z-25 Radioactive isotopes are those which ** ______________________________________.

Z-33 A chain reaction is said to be "critical" or "self-sustaining" when it ** ______________________________

z-8

charge on an electron
upward and downward velocities

---

z-16

deflected toward the negative plate
a positive charge.

---

z-24

neutrons have no charge so they are not slowed by the forces of attraction and repulsion (protons, unlike neutrons, have an electrical charge and are slowed by the forces of attraction and repulsion)

---

z-32

splits into two lighter nuclei, emitting some neutrons and releasing energy

---

z-40

the fusion of the hydrogen in the sun to form helium

z-1

atoms

consist of only one kind of atom

(165)

z-9

particles are shot through atoms, and the deflections of the particles are studied

z-17

like charges repel and unlike charges attract

z-25

have unstable nuclei which undergo spontaneous decay, emitting radiations and changing to a different element

z-33

can keep itself going (without an outside source of neutrons)

Z-8 Millikan, in his oil drop experiment, studied the amount of * by observing the difference in the * of the oil drops.

Z-16 As an alpha particle passes through an electric field, it will be ** because it has *.

Z-24 Neutrons are more penetrating than protons because ** .

Z-32 Nuclear fission is a kind of nuclear reaction in which a nucleus ** .

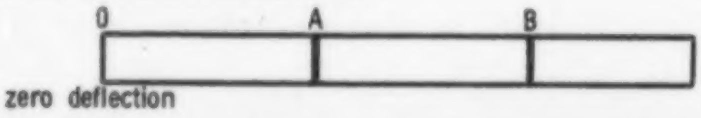
Z-40 The sun produces heat as a result of **

Z-2 All atoms have a similar structure which consists of **

(167)

Z-10 An element may have several isotopes, which means that **

Z-18 This mass spectrograph record indicates that **



Z-26 The age of bones of prehistoric animals can be determined by carbon dating. This is done by **

Z-34 A nuclear reactor consists of **

z-7

amount of matter in an object
force of attraction

---

z-15

$${}_8O^{16} + {}_0n^1 \longrightarrow {}_8O^{17}$$

---

z-23

the energy that holds nuclei together

---

z-31

the rate of decay of a radioactive isotope (the time required for half of a given number of atoms of a radioactive isotope to decay)

---

z-39

94
man-made element

z-2

a (positively charged) nucleus at the center with (negatively charged) electrons orbiting around it

z-10

atoms of an element can have different masses (the same number of protons but different numbers of neutrons in their nuclei)

z-18

the ions that struck the film at point A have a greater mass than those that struck the film at B

z-26

using a radiation counter to determine the relative amounts of radioactive carbon ($_6C^{14}$) and ordinary carbon in the bones

z-34

fuel, moderator, control rods (shielding and a method of removing energy in the form of heat)

Z-7 Mass and weight do not have the same meaning. Mass is the ** ________ while weight is a measure of the * ________ between objects.

Z-15 When $_8O^{16}$ is bombarded with a neutron, it absorbs the neutron and does not decay. The equation is

$ ____ + $ ____ ⟶ $ ____

Z-23 Nuclear binding energy is ** ________ ________.

Z-31 Half-life is a measure used to indicate ** ________ ________.

Z-39 Plutonium, $_{94}Pu^{239}$, has an atomic number of * ____. It is a * ________.

Z-3 An ion is an atom which is not ______ because it ** ______

Z-11 The Z number is the * ______ which indicates the ** ______. The A number is the * ______ which indicates the ** ______.

Z-19 Particle accelerators, such as the cyclotron, are used to ** ______

Z-27 There are three kinds of radioactive radiations, ** ______

Z-35 The energy output of a nuclear reactor is controlled by * ______, which ** ______

z-6

protons, electrons, and neutrons

protons have a positive charge, electrons have a negative charge, and neutrons have no charge (are electrically neutral)

---

z-14

$${}_{4}Be^{9} + {}_{1}p^{1} \longrightarrow {}_{5}B^{10} \longrightarrow {}_{2}He^{4} + {}_{3}Li^{6}$$

---

z-22

the relationship between mass and energy (that a small amount of mass can be converted to a large amount of energy)

---

z-30

a bundle of energy which makes up light and gamma rays (a particle-like bundle of radiant energy having no mass or charge, but having momentum)

---

z-38

fission is the splitting of a heavy nucleus into two lighter nuclei while fusion is the joining of two lighter nuclei to form a heavier nucleus

z-3

neutral

has too many or too few electrons (has a positive or negative charge)

⑰③

z-11

atomic number

the number of protons in the nucleus

mass number

the number of nucleons in the nucleus

z-19

accelerate particles to a high velocity

z-27

alpha rays (alpha particles), beta rays (electrons and positrons) and gamma rays

z-35

control rods

keep the chain reaction under control by absorbing some of the neutrons (so they cannot all cause more fuel to fission)

Z-6 The three basic particles in atoms are * . In terms of their charge, they differ in that ** .

Z-14 When beryllium, $_4Be^9$, is bombarded with a proton, it will become an isotope of boron, B, which immediately alpha decays to an isotope of lithium, Li. The equation is

$ + $ ⟶ $ ⟶ $ + $

Z-22 Einstein's equation, $E = mc^2$ indicates **

Z-30 A photon is ** .

Z-38 Fusion and fission are two kinds of nuclear reactions that produce energy. They differ in that ** .

Z-4 A neutral helium atom consists of ____________________.

Z-12 The symbol ${}_6C^{12}$ tells you that ____________________

Z-20 A cyclotron accelerates particles by ____________________

Z-28 During beta decay, an electron or positron is emitted even though none existed in the nucleus. This is possible because ____________________.

Z-36 Reactors need to be shielded in order to ____________________.

z-5

particles

electrons

they originate at the negative terminal (cathode) of a vacuum tube

z-13

$${}_7N^{14} + {}_2He^4 \longrightarrow {}_8O^{17} + {}_1p^1$$

z-21

the total number of nucleons

the actual mass compared to a standard amount of mass (1/16th of the ${}_8O^{16}$ atom)

z-29

detects radiations (detects and measures radiation) (counts radiations)

z-37

its chain reaction grows very large all at once (its chain reaction is not controlled)

z-4

a nucleus containing two protons and two neutrons with two electrons in orbit around the nucleus

---

z-12

the atom, an isotope of the element carbon, has a total of 12 nucleons, of which 6 are protons and 6 are neutrons

---

z-20

repeatedly passing the particles through an electric field

---

z-28

they are created at the instant they are emitted (a proton changes to a neutron or a neutron changes to a proton)

---

z-36

protect people near them from the dangerous gamma rays and high speed neutrons

Z-5 Cathode rays consist of small ______ called ______. The rays are called cathode rays because ** ______ ______

Z-13 When nitrogen, $_7N^{14}$, is bombarded with an alpha particle, it becomes oxygen, O, plus another particle. The equation is

$$_7N^{14} + \boxed{\$\quad} \longrightarrow \boxed{\$\quad} + \boxed{\$\quad}$$

Z-21 The difference between mass number and amu is that the mass number indicates ** ______ and amu means ** ______ ______.

Z-29 A Geiger counter is a device which ** ______ ______.

Z-37 An atomic bomb releases large amounts of energy because ** ______

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER Z-5

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER Z-13

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER Z-21

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER Z-29

TURN BOOK AROUND
AND CONTINUE WITH
ITEM NUMBER Z-37